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Classification *Changed*
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Auth: *Sec. 10501...*
11.5.1953
rec 5-5-54

ROYAL AIRCRAFT ESTABLISHMENT
FARNBOROUGH, HANTS

TECHNICAL NOTE No: AERO.2278

FLIGHT MEASUREMENTS
OF THE OSCILLATORY SPIN
OF A FIGHTER AIRCRAFT
(VAMPIRE 5)

by
D.R.DENNIS

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U.D.C. No. 533.652.1.011.3(42) Vampire 533.6.013.7/8

Technical Note No. Aero.2278

December, 1953

ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

Flight Measurements of the Oscillatory Spin
of a Fighter Aircraft (Vampire 5)

by

D. R. Dennis

R.A.E. Ref: Aero F/1352

M.O.S. Ref: AD/RDL1/B9

SUMMARY

A Vampire Mk.5 was instrumented and spun to determine the characteristics of the spin and recovery.

All spins were of two or four turns duration; normally entered spins were steep and oscillatory with large rolling and pitching oscillations present. The most violent oscillations occurred in the spins at 20,000 ft altitude, spins at 35,000 ft were less oscillatory and spins in which anti-spin aileron was applied were almost steady.

The peak angular velocity of the fuselage axis, applying a gyroscopic couple to the engine, was measured as 2.35 rads/sec in a spin at 20,000 ft altitude.

Recovery from four turn spins, by normal recovery action, was always satisfactory; but with rudder only centralised instead of reversed, recovery was doubtful.

The space attitude and motion was deduced from the spin records and some observations made as to the main features of the oscillations.

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Tech. Note No. Aero.2278

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1 Introduction

The De Havilland Vampire Mk.5 is a single seat jet propelled fighter aircraft in service with the R.A.F.

To cover the case of an accidental spin in service all fighter type aircraft are required to be able to recover from two turn spins and Service training requires that the pilots practice two turn spins in order to familiarize themselves with spin and recovery technique. Intensive practice spinning of Vampire 5's was proposed by the Air Ministry and it was required that the spin and recovery characteristics of the aircraft should be fully investigated at the R.A.E.

The primary object of the tests was to measure the aircraft angular velocities and accelerations in the spin. In addition the opportunity was taken to investigate other aspects of the spins. Spins were made with various control configurations at three different altitudes; and the recovery from the spin was investigated using different control movements.

2 Description of Aircraft2.1 Aerodynamics

A general arrangement drawing and data sheet for the aircraft is presented in figure 1. The aircraft has a wing loading of 39.4 lb/sq ft. The twin boom fuselage is of elliptical section and the tailplane spins the booms in a position below the rudders such that the 'inside' rudder in the spin is shielded (i.e. starboard rudder in a spin to starboard).

2.2 Loading of Aircraft (Full Fuel)

The aircraft was weighed with all fuel tanks full, 200 lbs ballast in the seat to represent the pilot and with all test equipment installed in the empty ammunition bays. (The particular aircraft Vampire VZ835 used in these tests was also fitted with an ejector seat.) Sufficient measurements were made to enable the position of the centre of gravity to be calculated.

The inertia loading of the aircraft was obtained from firms calculations as detailed in following table 1.

TABLE 1
Aircraft weight and inertias (full fuel)

VZ835 (Full Fuel)	Measured	Calculated from firms data	Remarks
Weight	10,283	-	
C.G. position U/cap from C.G. datum	0.625 ft aft of datum (29% M.A.C.)	-	
Pitching moment of inertia, B lbs/ft ²	-	224,000	Reduction of weight and inertias with fuel consumption obtained by calcula- tion based on firms data
Rolling moment of inertia, A lbs/ft ²	-	345,700	
Yawing moment of inertia, C lbs/ft ²	-	523,000	Inertias at spins are given in table 3

2.21 Estimation of Loading at Spin

During the climb to spinning height the fuel used caused an appreciable reduction in the weight and inertias of the aircraft. Fuel was mainly consumed from the wing tanks thus primarily reducing the rolling moment of inertia, A.

Therefore just before spins the pilot noted the amount of fuel consumed from the tanks and this figure was used to calculate the reduction in weight and inertias from the full fuel condition. The calculated loadings of the aircraft at each spin are included in the summarised spin results of table 3.

3 Measurements Made3.1 Aircraft Instrumentation

The instrumentation detailed in the following table 2 was installed in the aircraft.

TABLE 2

Details of Instruments

Instrument	Quantity Measured	Range	Natural frequency and damping of system	Definition of quantities	Remarks
Rate Gyro	Rate of Roll p'	± 5 rads/sec	11 cycles/sec	Roll to Stbd.	Desynn transmission system
Rate Gyro	Rate of Yaw r'	± 4 rads/sec	0.4 damping	Yaw to Stbd.	Air dashpot damping.
Rate Gyro	Rate of pitch q'	± 1.75 rads/sec	(average)	Pitch nose up	Gyro's sealed in pressure boxes.
Z' Accelerometer	Normal Acceleration	-1 +5 'g'	11 cycles/sec	Upwards along Z' axis	Desynn transmission system
Y' Accelerometer	Acceleration along wings	± 1 'g'	0.45 damping (average)	Along stbd. wing	Friction damping
Rudder Desynn	Rudder angle	$\pm 30^\circ$	10 cycles/sec 0.2 damping	Stbd.	Measured on stbd. rudder
Altimeter	Altitude	0-50,000 ft	Static error large in spins	-	-
R.P.M. gauge	Engine Revolutions	0-15,000 rpm	-	-	-
G.S.A.P. camera	Instrument Dials	16 frames/sec	-	-	-
Timing Clock	Time Seconds	-	-	-	-

The instrument readings were presented, and photographed by a G.S.A.P. camera, in an auto-observer installed in the front starboard ammunition bay.

The three rate gyros were mounted in the port front ammunition bay to measure rates of roll pitch and yaw about the aircraft body axes. The accelerometers were as close to the C.G. as possible in the port rear bay, to measure accelerations along the aircraft Z' and Y' body axes; their measurements were presented by the Desynn system on receivers in the auto-observer. The actual position of the accelerometers was 2.5 ft in front of the C.G. and 1.5 ft to port. Small corrections are therefore necessary to the spin acceleration records to obtain the actual aircraft accelerations at the C.G.

3.2 Body Axes System of Measurement

The aircraft body axes are mutually at right angles and originate at the aircraft C.G. (The X' axis is defined in figure 1.) Positive directions of the angular velocities and accelerations are defined in table 2 and figure 2.

Sufficient measurements were made about and along the aircraft axes to enable calculations to be made of the acceleration and gyroscopic stresses in the spin, on airframe and engine respectively. Measurement of the X' acceleration was not made as spin measurements on other aircraft¹ have shown it to be small. The stresses on the aircraft in the spin are discussed in a later section 6.32.

The sketch of figure 2 shows the body axes system in relation to the spin geometry. The space attitude and motion of the aircraft can be calculated from the body axes measurements if a steady spin is obtained. The method of calculation is as described in section 4.

4 The 'Prototype' Spin

It has been shown² that a close approximation, considerably simplifying the spin geometry, can be made by postulating that the Z' body axis intersects the spin axis. Any departure of the wings from the horizontal position can then be obtained by yawing the aircraft about the Z' axis as shown in the diagram of figure 2. The following relationship apply:-

$$p' = \Omega \cos \alpha \cos \chi \quad (1)$$

$$r' = \Omega \sin \alpha \quad (2)$$

$$q' = \Omega \cos \alpha \sin \chi \quad (3)$$

$$\text{from (1) and (3)} \tan \chi = \frac{q'}{p'} \quad (1) \text{ and (2)} \quad \frac{r'}{p'} = \frac{\tan \alpha}{\cos \chi}$$

from balance of horizontal forces

$$R = \frac{Z_g g \cos \alpha}{\Omega^2}$$

(Note) R as calculated is from spin axis to Z' accelerometer.

$$\text{Helix angle of C.G.} = \frac{R_{C.G.} \Omega}{V_D} = \tan \gamma$$

and aerodynamic sideslip $\beta^0 = \theta_y - \gamma$

where $\sin \theta_y = \sin \chi \cos \alpha$.

These relationships are true only for steady spins, in rough oscillatory spins where the angular velocities and accelerations are rapidly changing they do not apply.

However mean angular velocities and accelerations can be obtained from the records from which the mean attitude and rate of rotation in the oscillatory spin can be calculated.

In general the Vampire spins were very oscillatory and the calculated space quantities summarised in table 3 are intended to give a general indication of the aircraft's mean space attitude and motion in the oscillations of the third and fourth turns.

5 Flight Tests

5.1 Method of Test

Spins from straight and level flight were commenced by throttling back the engine and reducing speed until the aircraft was near the stall, when the spin was entered by applying full up elevator and full rudder in the required direction of spin.

Throughout the tests the particular aircraft used showed a left wing drop at the stall and this affected the entry to the spin in each direction and probably the eventual roughness of the spin.

The pilot attempted to hold on full rudder throughout the spins but on some occasions buffeting caused the rudder to move from the stops. As far as possible throughout the spins and recoveries the ailerons were kept central except in the case of spins (records 7, 14, 15) where aileron was deliberately applied.

Except where stated otherwise, recovery from spins was by normal recovery action (full opposite rudder and moving the stick forward until the spin stops) the aircraft recovering into a steep dive, often over the vertical, from which a 'pull out' was made.

Care had to be taken that the 'pull out' was gentle as the aircraft tended to stall due to the acceleration load and spin again.

6 Results and Discussion

The auto-observer records of the spins and recoveries are presented in figures 3-16. All measurements made are plotted on a common time base; time zero corresponding to an instant at the stall just prior to entry to the spin. The first part of the 'pull out' only is shown at the end of the records.

Table 3 summarises the results obtained in the spins and the mean spin quantities calculated from the results.

All spins show a common feature in that there is an increase in the spin angular velocities and accelerations as the spin progresses. All spins, with the exception of that with anti-spin aileron applied, were oscillatory; the violence of the oscillations varying with the altitude of the spin, the applied controls, and the spin direction. In general spins to starboard were rougher than to port.

The records show that the oscillations are primarily in roll and pitch (about body axes) and are cyclic with each turn; increasing in amplitude up to the fourth turn of the spin. There is some indication from the records that the oscillations have reached maximum amplitude at the fourth turn of the spin.

TABLE 3 - RESULTS OBTAINED FROM SPIN RECORDS

Spin Record No. Fig.	Turns Part or Snd. Fig.	Spin and Controls	Height of Entry ft	Aircraft Condition at Spin						Body Axes Measured from Records During Spin Turns 3-4						Mean Calculated Values						Remarks	
				W lbs	A lbs/ft ²	B lbs/ft ²	C lbs/ft ²	Weight, Inertia C.G.	Angular Velocities Rads/sec	Accelerations Rads/sec ²	Rate Descent ft/sec	Time Recover tsecs	X ⁰ α ⁰ rads sec	Ω ⁰ rads sec	R.C.G. ft	θ ⁰ C.G.	ρ ⁰ C.G.						
3	2.T.S.	Normal Entry and Pro-Spin Controls	20,000	8,400	235,000	219,000	407,000	0.272															
4	2.T.P.	N	20,000	8,250	225,000	218,000	397,000	0.269															
5	2.T.S.	N	36,000	8,750	255,000	220,000	428,000	0.278															
6	2.T.P.	N	35,000	8,800	247,000	219,000	420,000	0.276															
7	2.T.S.	Normal Entry Anti-Spin Gilleron in Spin and Recovery	30,000	8,580	245,000	219,500	418,000	0.275															
8	4.T.S.	N	20,000	8,520	241,000	219,500	415,000	0.275	2.0	+0.7	1.05	1.1	0.6	230	2.7	19.3	28.3	6.8	4.0	17.2	13.2	Very Rough Oscillatory Spin	
9	4.T.P.	N	20,000	8,580	245,000	219,500	418,000	0.275	2.05	-0.15	1.25	1.05	0.45	230	3.4	-4.2	31.3	2.41	6.3	3.8	-5.6	-7.4	Very Rough
10	4.T.S.	N	35,000	8,650	250,000	220,000	423,000	0.276	2.15	+0.5	1.05	0.8	0.35	264	2.9	13.1	25.5	2.44	5.05	2.7	11.8	9.1	Rough
11	4.T.P.	N	35,000	8,700	253,000	220,000	425,000	0.277	1.65	-0.1	1.0	0.9	0.35	250	3.0	-3.45	31.2	1.94	7.9	3.5	-3.0	-6.5	Small Oscillation
12	3.T.S.	Entry from '16' Small Controls N	20,000	8,500	240,000	219,500	412,000	0.274	2.1	+0.8	1.15	1.0	-	250	3.5	20.8	27.3	2.51	6.0	3.4	18.4	15.0	3 turns Spin Only

*Calculated Spin Radius has been Corrected to:- Spin Axis to A/C G.C.

TABLE 3 (CONT'D)

Spin Turns Per Sec. or R.P.M.	Spin Rate and Controls	Height of Entry ft	Aircraft Condition at Spin						Mean Values Measured from Records During Spin Turns 3-4						Mean Calculated Values					
			W lbs	A lbs/ft ²	B lbs/ft ²	C lbs/ft ²	C.G. ft	Angular Velocities Rads/sec	Accelerations	Decent- Rate	Time Recover	χ ^o	α ^o	Ω rads/ sec	β ^o C.G.	β ^o C.G.				
13	4.T.P.	29,000																		
		Entry from 10° Stall Controls N																		
14	4.T.P.	30,000																		
		Normal Entry Pro-Spin Allaron Throughout																		
15	4.T.P.	30,000																		
		Normal Entry Anti-Spin Allaron Throughout Spin																		
16	4.T.P.	30,000	8,650	250,000	220,000	423,000	0.276	1.75	0	1.0	1.15	0.3	225	7.0 Not out	0 29.7 2.02	9.10 4.7	0 -4.7			
16a	4.T.P.	Repeat of Above	30,000	8,700	253,000	220,000	425,000	0.277	-	-	-	-	-	9.0 out	-	-	-			

*Calculated Spin Radius has been corrected to:-- Spin Axis to A/C C.G.

The altitude records show large errors in the spin due to the attitude at which the pitot static is working; mean rates of descent only are obtainable from these records.

6.1 Normal Spins

Normally entered spins consisted of two and four turn spins at different altitudes as recorded in figures 3-6, 8-11.

In the two turn spins, figures 3-6, the records show that the spin is not fully developed, the maximum angular velocities measured being 3.2 radians/sec in roll, 1.25 radians/sec pitch and 1.1 radians/sec in yaw. The four turn spins figures 8-11 are directly comparable. These records show that spins at 35,000 ft altitude are considerably less oscillatory than at 20,000 ft. In the normal four turn spins at 20,000 ft the highest angular velocities recorded are, 4.15, 1.5, 2.0 radians/sec in roll, yaw and pitch respectively. At 35,000 ft altitude the corresponding peak angular velocities recorded are 3.9 (in recovery), 1.3 and 1.3 radians/sec. The normal acceleration in the spins was small not exceeding 1 'g' at 35,000 ft and 1.6 'g' at 20,000.

Taking mean values from the records for this acceleration and for the angular velocities and rate of descent after 3-4 turns of these spins, the spin quantities shown in table 3 have been calculated. The mean incidence is in the range 26-31° and the rate of rotation 2.0-2.4 radians/sec.

These spins can therefore be described as steep oscillatory spins in which the oscillations are predominately roll and pitch about aircraft body axes. In the very oscillatory spins the incidence range in the oscillatory motion is probably from 20-60°, and the wing tilts 'inner wing down' to angles of the order of $\pm 30^\circ$ or more during the oscillations. The results confirm the pilot's summary of these spins as follows:- "All spins were fairly steep with the nose of the aircraft averaging about 30° to the vertical. The spin to the right was faster and rougher than to the left, and the lower the altitude the more oscillatory was the spin".

The spin oscillations are further discussed in a later section 6.31.

6.2 Spins from 'g' Stalls

Spins from 'g' stalls were entered from turning flight the turn being tightened until the aircraft stalled at about 1.6g, when rudder was applied in the direction of spin. The spin records figures 12 and 13 indicate that from a 'g' stall the spin development is quick and high angular velocities occur in the first turn. Comparison of these spins with normally entered spins show that spins from 'g' stalls can lead to the higher stresses in the first two turns.

6.3 Spins with Applied 'Aileron'

Figure 14 is a record of a spin entered at 30,000 ft from straight and level flight with 'pro-spin' aileron applied throughout the spin. Figure 15 is of a similarly entered spin with 'anti-spin' aileron applied ('anti-spin' aileron is aileron in opposition to the spin direction, e.g. stick right in a left hand spin).

The records show that aileron application has a large effect on the spins, the spin with anti-spin aileron being almost steady (figure 15). In this spin the rate of roll shows an almost steady increase and the

rate of pitch is 'nose down' with only small oscillations present. In this steady spin the rate of pitch does not become positive as in the case of the oscillatory spins.

The calculated aircraft motion and attitude in space in this spin is shown in figure 18; the spin was sufficiently steady for these calculated results to be accurate values.

The spin with pro-spin aileron was oscillatory with a 'build up' and angular velocity range similar to that in the normal spins.

6.4 The Spin Recoveries

There was very little asymmetry between recoveries from each direction of spin, from four turn spins in either direction recovery time never exceeded 3.5 seconds. (Recovery time is defined as time elapsing between application of opposite rudder to reduction of rate of yaw to less than 0.2 rads/sec). There was no indication that when normal recovery action was applied the recovery was other than positive at either altitude.

The recoveries using 'pro' and 'anti-spin' aileron in conjunction with normal recovery action show little difference in recovery time, the application of anti-spin aileron being slightly more favourable to recovery. This result is in agreement with predictions of aileron effect for the aircraft based on model tests³.

Figure 16 is a record of a spin in which restricted control movements were used in recovery. It will be seen from the record that with centralised rudder only, and stick forward for recovery, recovery has not taken place in 7 seconds, whereupon the pilot applied full oppositer rudder and effected recovery. This spin and recovery was repeated by another pilot who applied 5° of opposite rudder in recovery action, full recovery then being effected after 8.8 seconds. (Rudder trace figure 16a.)

These results are a measure of the aircraft's ability to recover from four turn spins and show that recovery is doubtful when 'opposite' rudder is not used, and delayed for 6 seconds when only 5° of anti-spin rudder is applied.

These results show that while recovery is quite satisfactory from four turn spins by normal recovery action, the margin of safety is not high if the controls are mis-applied in recovery action.

6.5 General Discussion

Comparison of the four turn spin results for the Vampire with those of other aircraft shows the Vampire to have one of the most oscillatory spins yet measured. Examination of the spin results shows the character and possible cause of the oscillations, and indicates that the oscillations may lead to high stresses in the engine and portions of the airframe. These features are discussed in the following sections.

6.51 The Spin Oscillations

The angular velocities and accelerations, and aerodynamic forces and moments acting on the aircraft throughout the spin, are dependent on the aircraft's motion and attitude in space during each turn.

Use of the relationships of section 4 to give aircraft space attitude of motion at any instant in a semi-oscillatory spin can give approximate values only. Such results however can be most useful in making a fair reconstruction of the oscillatory motion of the aircraft in space during the spin.

This has been done for the semi-oscillatory spin of figure 11, the calculated angles of incidence, wing tilt, rate of rotation and spin radius obtained are plotted on the same time base as the spin measurements in figure 17.

From figure 17 the aircraft's space motion in the oscillatory spin can be reconstructed as follows:- At time 6 seconds on the record the aircraft's incidence is decreasing to reach its minimum at time 8.0 secs, during this period the rate of rotation increases and its principal component rotation in body axes is in roll, which therefore also increases. The 'outer' wing is down and this gives rise to a nose down rate of pitch about body axes (see figure 2 and equation (4) section 4). Peak rate of rotation and minimum incidence occur together and the wing tilt is changing from 'outward' to 'inward'. The spin incidence then increases and the rate of rotation decreases; during this phase the wing tilt is inward (giving rise to nose up rate of pitch about body axes) until just before maximum incidence is reached, when the wing tilt becomes 'outer' wing down once more. Maximum incidence, minimum rate of rotation and roll about body axes are coincident and then the oscillation cycle is repeated with a reduction in incidence accompanied by an increase in rate of rotation, a turn of the spin being completed at time 10.6 seconds on record.

This reconstruction of the motion agrees with pilots' reports of the oscillations in that the peak rate of roll occurred when the aircraft was in a near vertical attitude and was a minimum when the aircraft's incidence was at its maximum. The reconstruction also shows that, the wing tilt is changing from 'inwards' to 'outward' in a cyclic motion during each turn of the spin.

The incidence at the 'outer' wing tip during the spin oscillations has been calculated from relationship $\alpha_{tip} = \alpha - \tan \frac{-10b}{2V}$. The results (figure 17) show that in the steep incidence, high rate of rotation phase of the spin oscillations, the outer wing must be unstalled for a short period and then restalls as the incidence increases. The occurrence of this unstalling in phase with the oscillations would prevent any possible balance of the spin couples at small incidence in the spin.

A steady spin was only possible with anti-spin aileron applied in the spin; calculation of the outer wing tip incidence in this spin shows that it is unlikely that the outer wing tip unstalls. The calculated space attitude and motion in this spin is presented in figure 18; the spin was steady enough for the calculation to give accurate space quantities.

Comparison of the space quantities for this spin with the mean values obtained for the semi-oscillatory spin with neutral ailerons, figure 17, shows that the primary effect of the applied anti-spin aileron is to make the wing tilt more negative. This implies that simultaneous balance of the spin couples in roll, yaw and pitch requires a steady negative wing tilt in the spin (i.e. negative sideslip), and when this is not obtainable, in spins with neutral ailerons, on oscillatory spin results.

6.52 The Stresses on the Aircraft in the Spin

In the Vampire oscillatory spins the high angular velocities in pitch and yaw which occur apply a gyroscopic couple to the rotating compressor and turbine disc of the engine. The magnitude of the couple depends on the angular velocity of the aircraft fuselage axis, the engine revolutions, and the polar moment of inertia of the rotating part i.e.

$$\text{Couple} = I \sqrt{r'^2 + q'^2} \times \text{engine revolutions.}$$

This couple has two effects on the engine:-

1. A direct stress on the rotating discs and couplings, and a resultant shaft load on the engine bearings.
2. Fatigue of the rotating parts of the engine.

In the case of the Vampire spins at 20,000 ft altitude, the maximum angular velocity of the fuselage axis recorded was 2.35 radians/second, and the engine idling r.p.m. was 4,700 r.p.m. In spins at altitude 35,000 ft the maximum angular velocity recorded was 1.48 radians/second and the corresponding engine idling r.p.m. 7,800.

The standard technique before carrying out test or practice spins is to throttle back the engine speed to idling r.p.m. which is of necessity increased with increase of altitude. Fortunately spins at altitude are less oscillatory and the two effects tend to cancel out, in the case of the Vampire the results show that the gyroscopic couple on the discs and shaft of the engine is slightly greater at the higher altitude.

In an accidental spin such as might occur in combat the aircraft could spin with the engine at full r.p.m. and this combined with a violent oscillatory spin would be the critical stressing case for the engine.

The gyroscopic couple is such that with each revolution of the engine the disc flange and attachment bolts are alternatively put into tension and compression. This factor may have to be considered in assessing the fatigue life of the engine if Vampire aircraft are to be used regularly for practice spins.

Acceleration in the spin, at the aircraft C.G., due to the aircraft's space motion, are small; the normal acceleration did not exceed 1.6 'g' in the spins and that along the Y' axis 1.0 'g'. Accelerations, at parts of the aircraft distant from the C.G., due to the aircraft's own rotations can be large, particularly at the wing tips and the outer wing tank position. This is due to the high rates of roll as measured in the spin. In the spin of figure 9 where a peak rate of roll of 4.15 radians/second occurred, the outer wings tanks have 6.2 'g' acting outwards on them due to roll and 0.63 'g' due to rate of yaw; this is in addition to the Y' acceleration at the C.G.

6.53 The Physiological Effect of Violent Spins

In the more-violent oscillatory spins the motion had an effect on the physical senses of the pilot. The principal effects noted by the pilot were dizziness and disorientation, principally in recovery, and as an after effect, a reluctance to apply much normal 'g' in the pull out from the recovery dive.

The disorientation principally manifested itself in inability to focus the eyes for a short period and this may be attributed to the high rates of roll occurring during spin and recovery.

The physical effects of the violent oscillations are acceptable for experienced pilots but raises the question of their possible confusing effect on inexperienced pilots practising spinning on the aircraft.

7 Conclusions

All normal spins, up to four turns, of Vampire VZ835 were oscillatory. The oscillations were primarily in roll and pitch about aircraft body axes and cyclic with each turn of the spin.

High angular velocities were recorded in the oscillatory spins; maximum values measured were:- angular velocity of the fuselage axis 2.35 radians/second, and rate of roll 4.15 radians/second, in a spin at 20,000 ft altitude. Spins at 35,000 ft were less oscillatory.

Reconstruction of the space motion during the oscillatory spin shows that peak rate of roll and minimum incidence, minimum rate of roll and maximum incidence occur in phase in the oscillations.

Anti-spin aileron applied throughout the spin had the effect of making the spin almost steady; with applied pro-spin aileron the spin was oscillatory.

Recovery from the four turn spin by normal recovery action was always satisfactory. With rudder only centralized instead of reversed, recovery was doubtful.

LIST OF SYMBOLS

- Ω radians/second, rate of rotation of aircraft about vertical spin axis
- α degrees, wing incidence to vertical at plane of symmetry
- V_D ft/second, vertical rate of descent
- V_F ft/second, air speed along flight path
- $R_{C.G.}$ ft, spin radius (aircraft centre of gravity to spin axis)
- γ degrees, angle of helical path of C.G. to the vertical spin axis
- χ degrees, angle of rotation of wing, about normal Z' axis, from the wings horizontal position (+ 'inner' wing down)
- θ_y degrees, angle of tilt of wing to horizontal plane (as seen in a film view of spin from side, and positive inner wing down)
- β degrees, aerodynamic sideslip angle (i.e. angle which relative wind makes with the aircraft plane of symmetry, positive for inward sideslip)
- p' radians/second, rate of roll of aircraft about X' body axis (+ to starboard)
- q' radians/second, rate of pitch of aircraft about Y' body axis (+ nose up)
- r' radians/second, rate of yaw of aircraft about Z' body axis (+ to starboard)
- $Z'g$, acceleration in 'g' units along Z' body axis (+ upwards)
- $Y'g$, acceleration in 'g' units along Y' body axis (+ starboard)
- N aerodynamic force normal to wing chord
- W lb, aircraft weight
- A lb ft², Rolling moment of inertia.
- B lb ft², Pitching moment of inertia.
- C lb ft², Yawing moment of inertia.

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Tech. Note No. Aero.2278

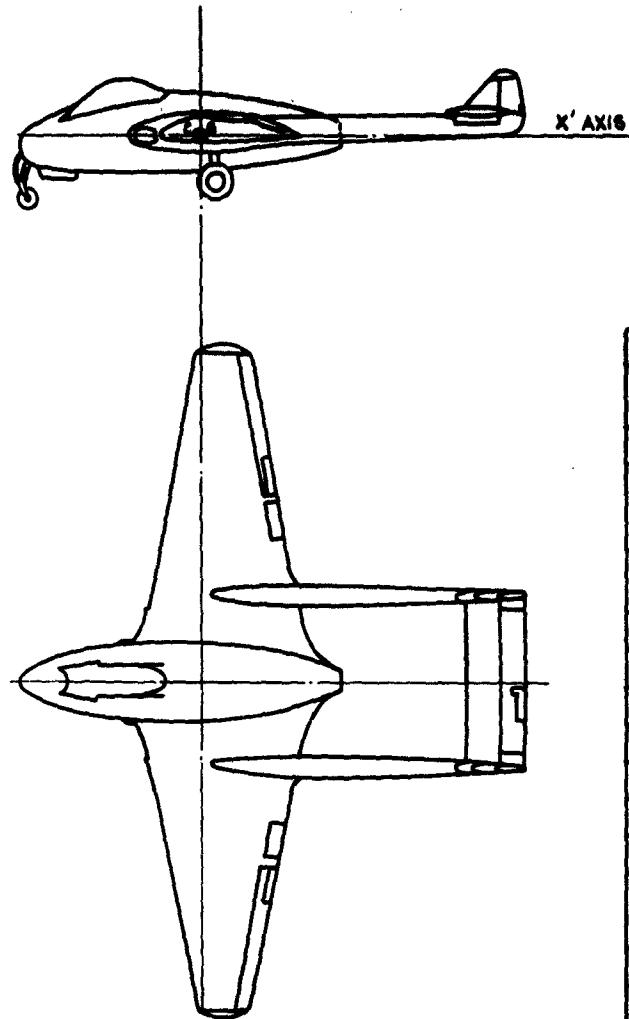
REFERENCES

<u>No.</u>	<u>Author</u>	<u>Title, etc.</u>
1	T.H. Kerr and D.R. Dennis	Model and Full Scale Spinning Tests on a Conventional Straight Wing Aircraft (Balliol Mk.2). Report Aero.2480, February 1953.
2	S.B. Gates and L.W. Bryant	The Spinning of Aeroplanes. R & M 1001, 1927.
3	D.J. Harper	The Influence of Rolling Moment on the Spin and Recovery as Observed in Model Spinning Tests. R.A.E. Report No. Aero.2365.

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GENERAL DATA		
* WEIGHT (FULL FUEL) , W LB (330 GALLS.)	10,283	
ENGINE	ROBINS MIL	
* C.G. (FULL FUEL) AFT LIMIT, IN AFT OF DATUM (29% MAC)	0-828 FT.	
MOMENT OF INERTIA LB.FT ² A (FULL FUEL)	345,700	
MOMENT OF INERTIA LB.FT ² B (FULL FUEL)	224,000	
MOMENT OF INERTIA LB.FT ² C (FULL FUEL)	523,000	
WING AREA (GROSS), SQ.FT.	261	
SPAN , B FT.	36	
MEAN CHORD E , FT	6-87	
WING LOADING , LBS./SQ.FT.	39-4	
TOTAL TAIL SURFACE, S' SQ.FT.	37	
ELEVATOR ANGLE , DEGREES	UP 20	
	DOWN 11	
FIN AND RUDDER AREA, S' SQ.FT.	7-97	
RUDDER ANGLE, DEGREES	PORT 25	
	STBD. 25	

* MEASURED VALUES.

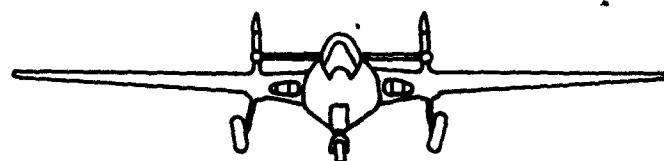


FIG.1 AERODYNAMIC DATA SHEET. VAMPIRE VZ 835

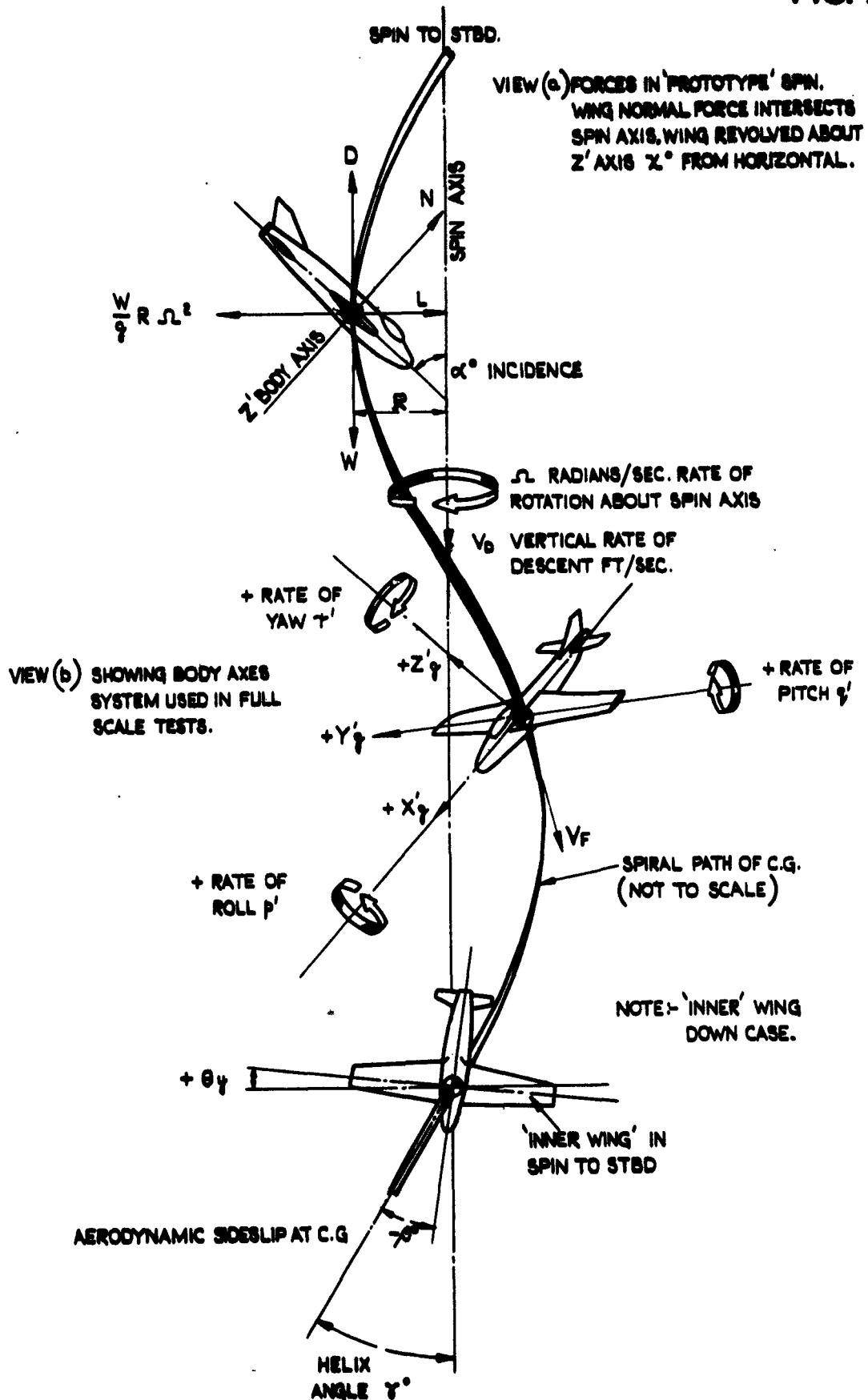


FIG. 2 SKETCH OF 'PROTOTYPE' STEADY SPIN.

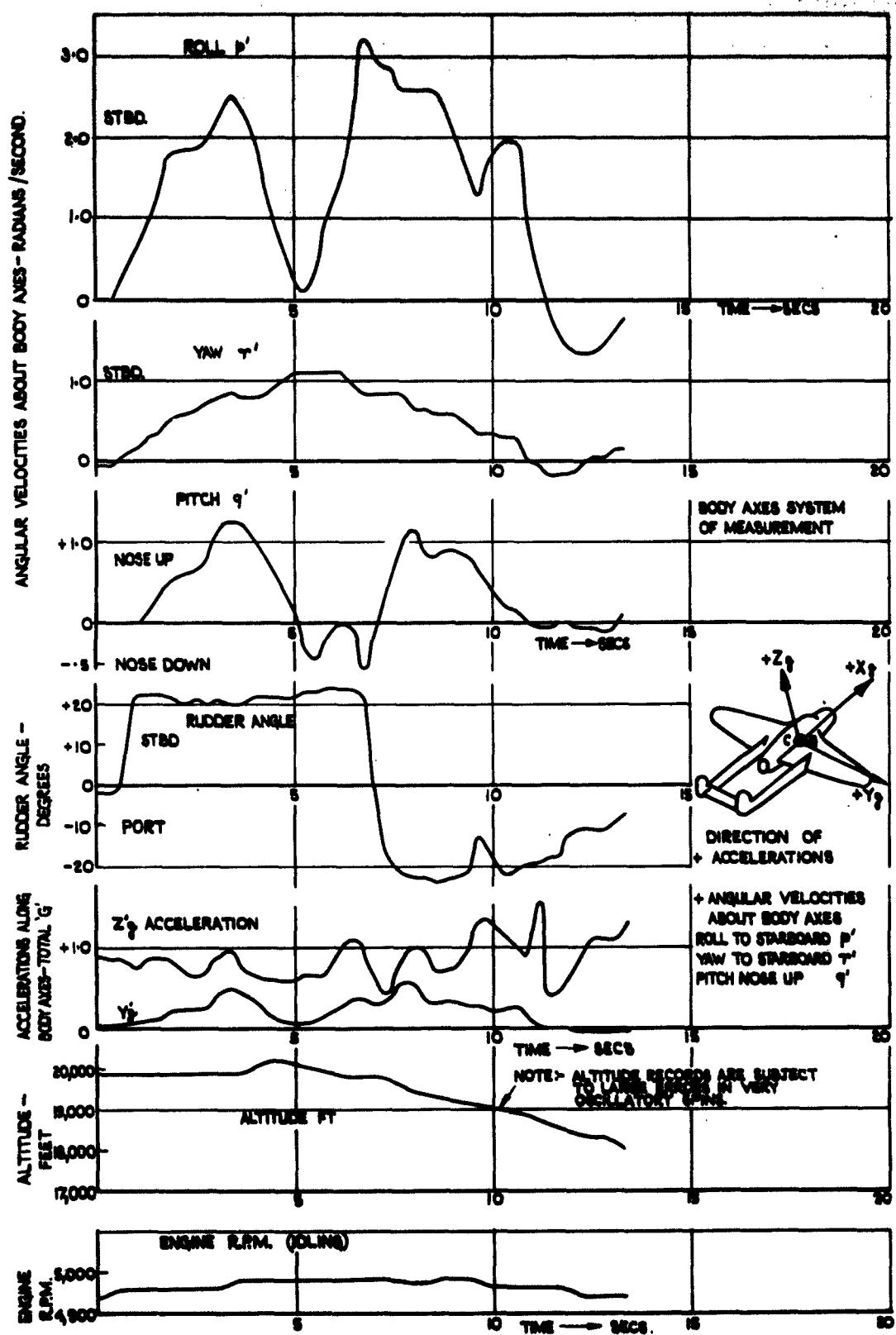


FIG. 3 2 TURN SPIN TO STARBOARD (ALTITUDE 20,000 FT)

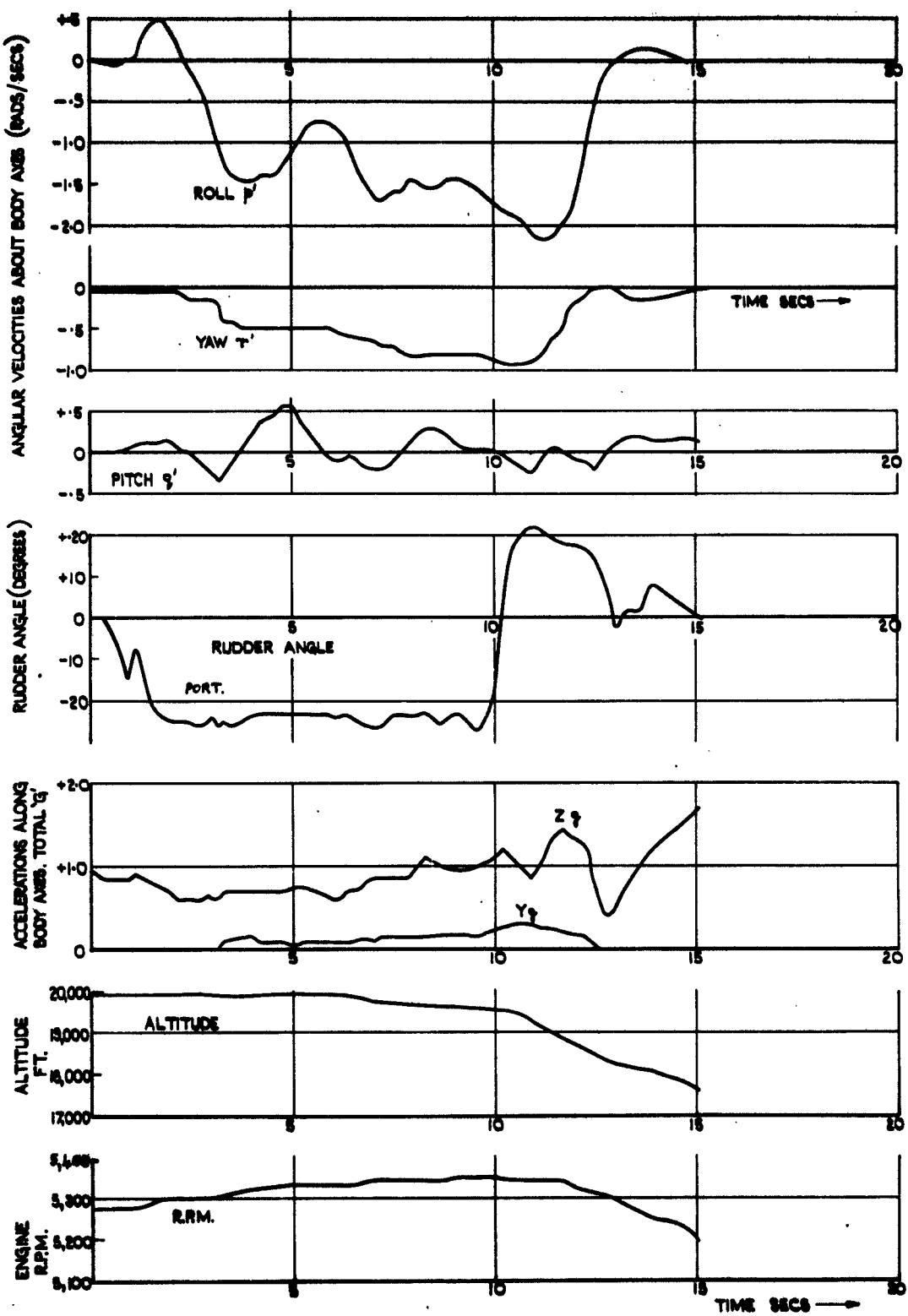


FIG.4 2 TURN SPIN TO PORT (ALTITUDE 20,000 FT.)

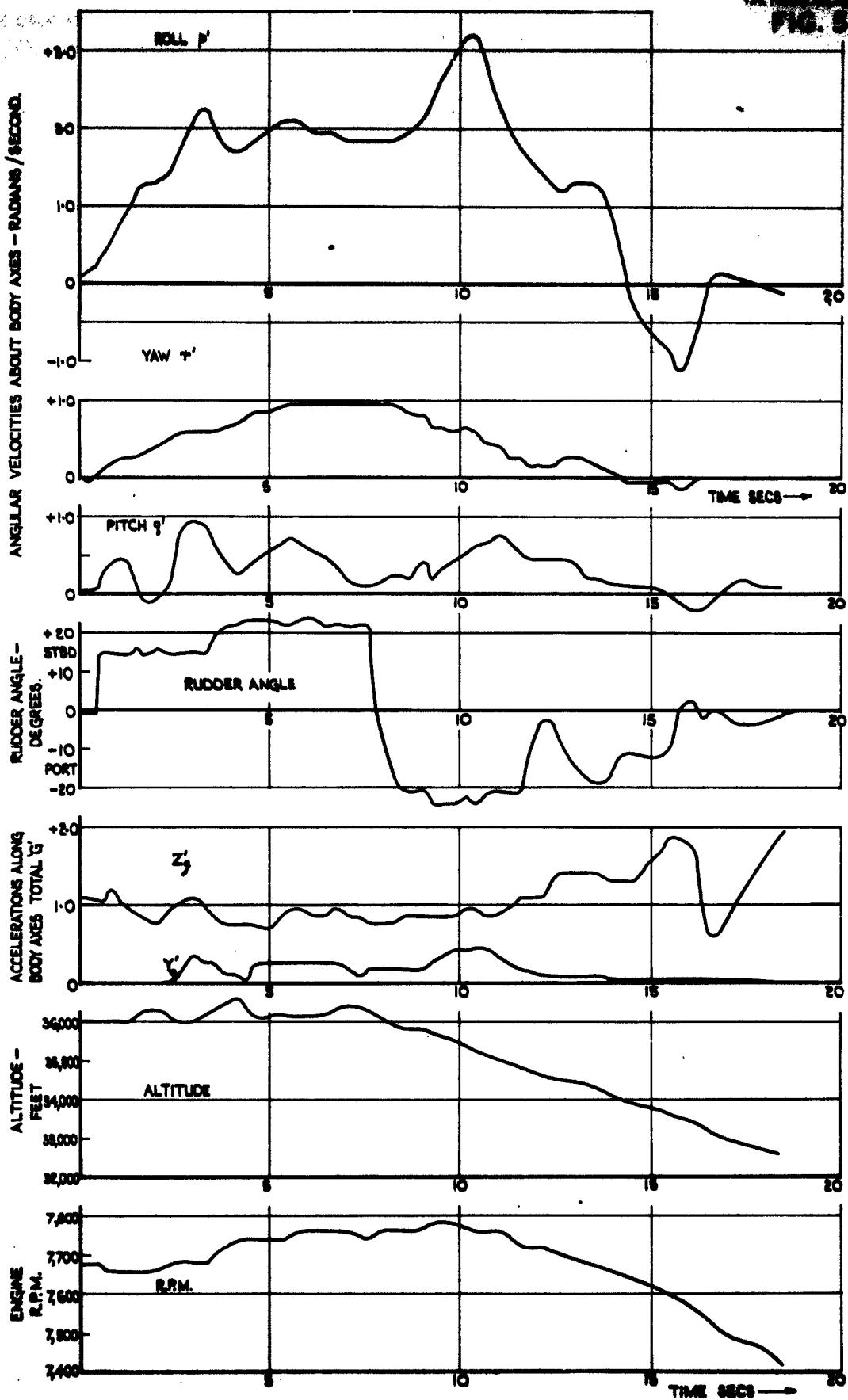


FIG. 5 2 TURN SPIN TO STBD. (ALTITUDE 35,000 FT.)

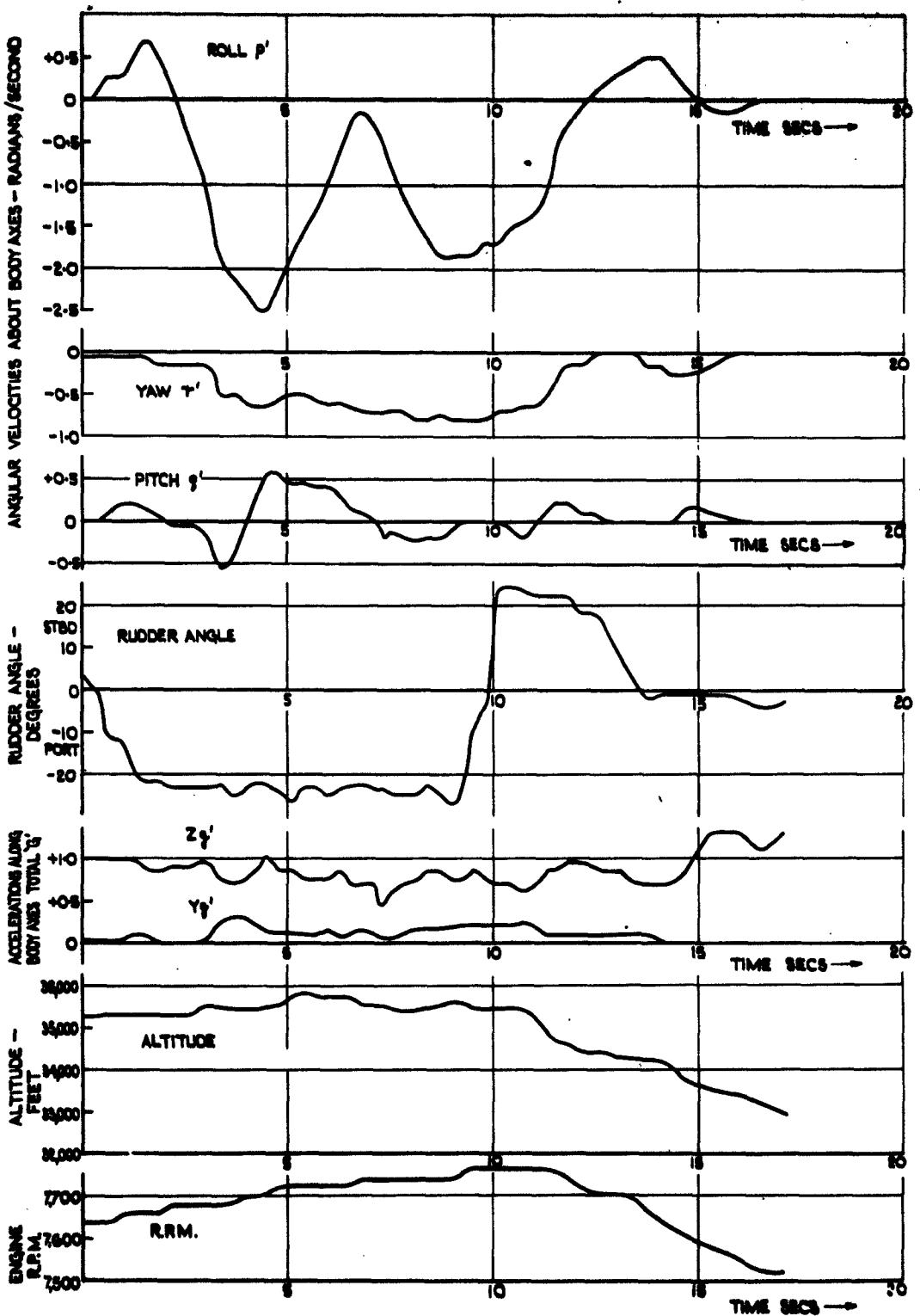
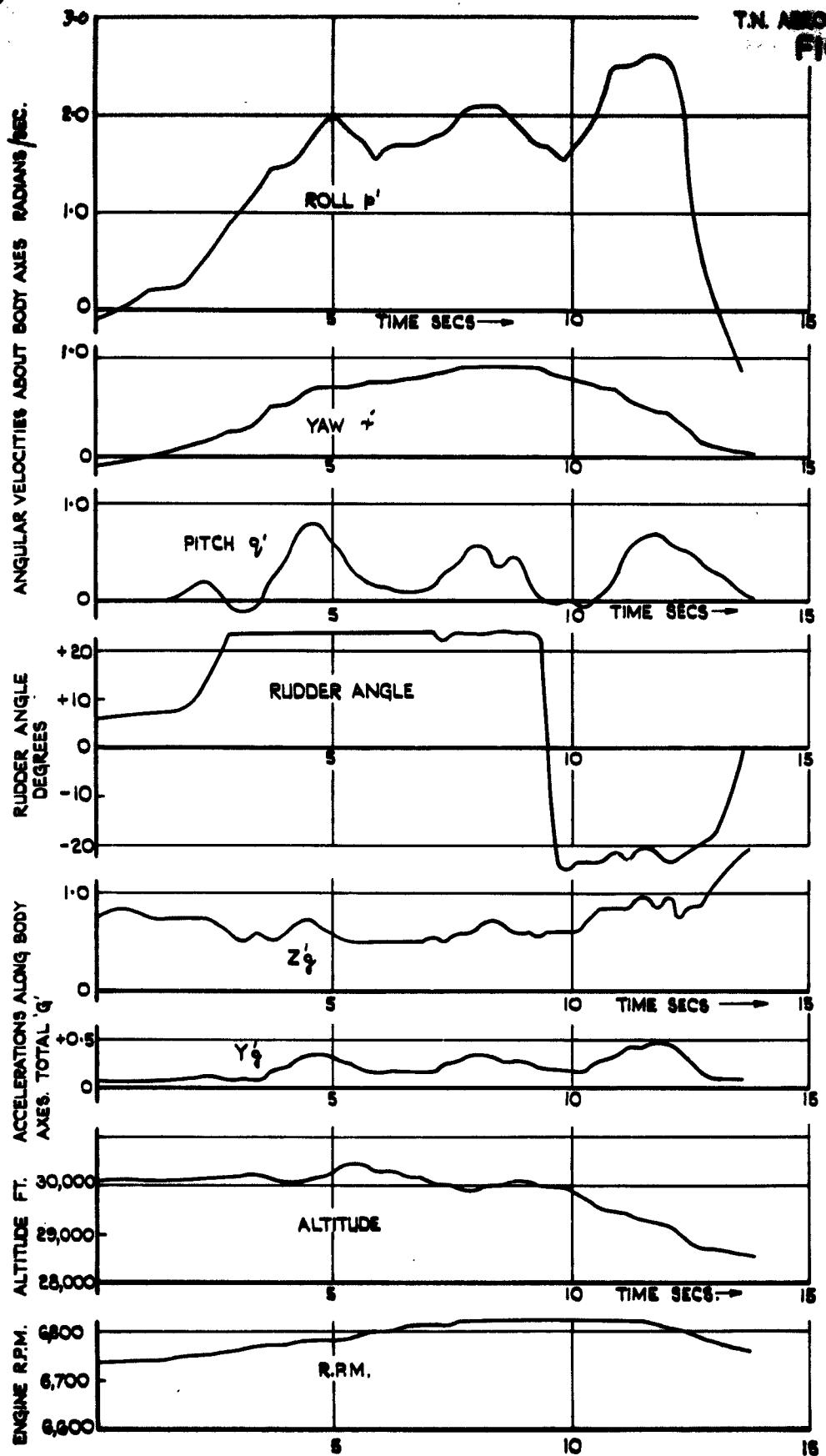


FIG. 6 2 TURN SPIN TO PORT (ALTITUDE 35,000 FT.)

29612 6

T.N. ANGLES 29612
FIG. 7.

**FIG. 7. 2 TURN SPIN TO STB'D. WITH ANTI- SPIN
AILERON THROUGHOUT SPIN + RECOVERY
(30,000 FT.)**

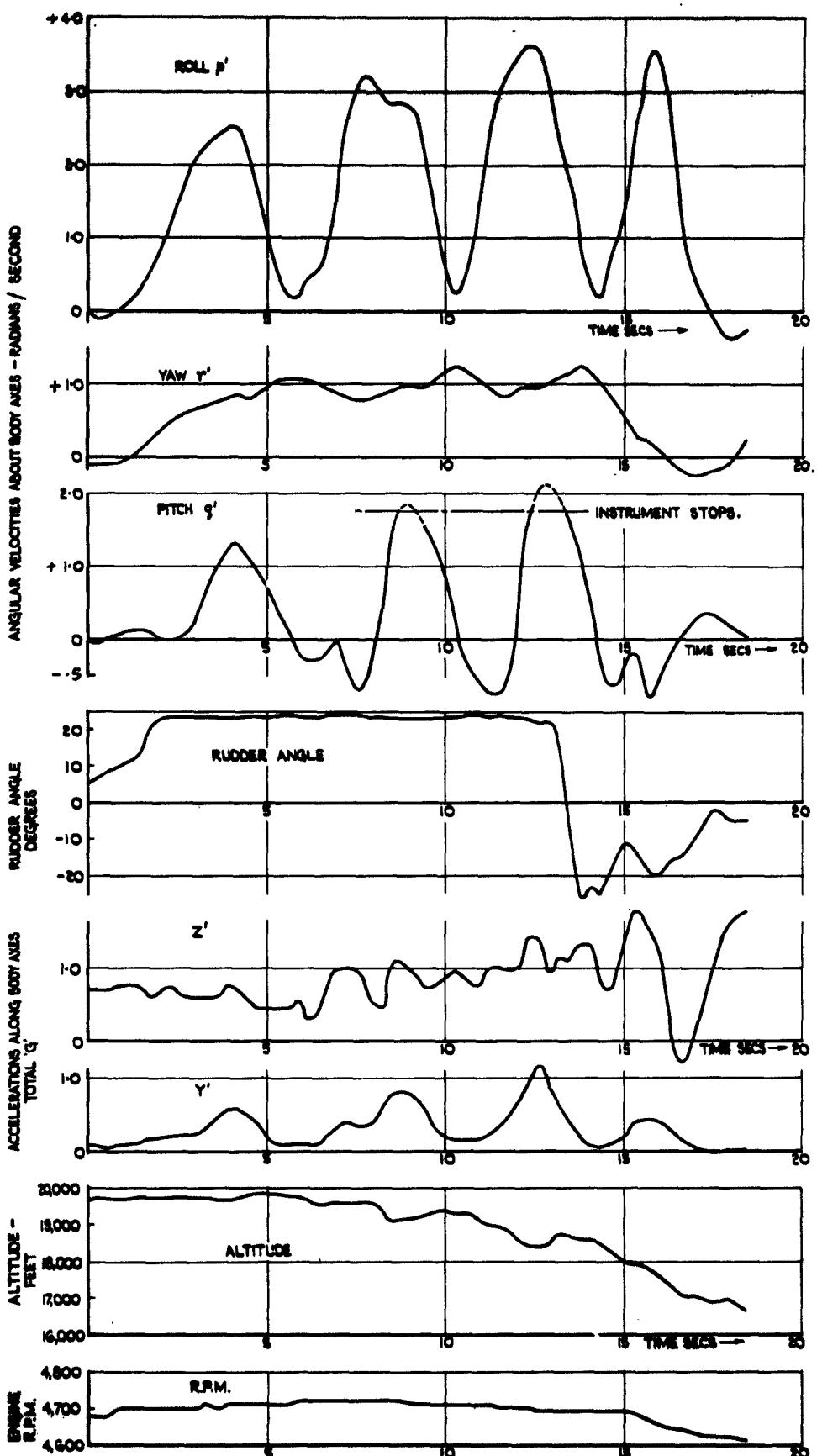


FIG. 8 4 TURN NORMAL SPIN TO STARBOARD FROM 20,000 FT.

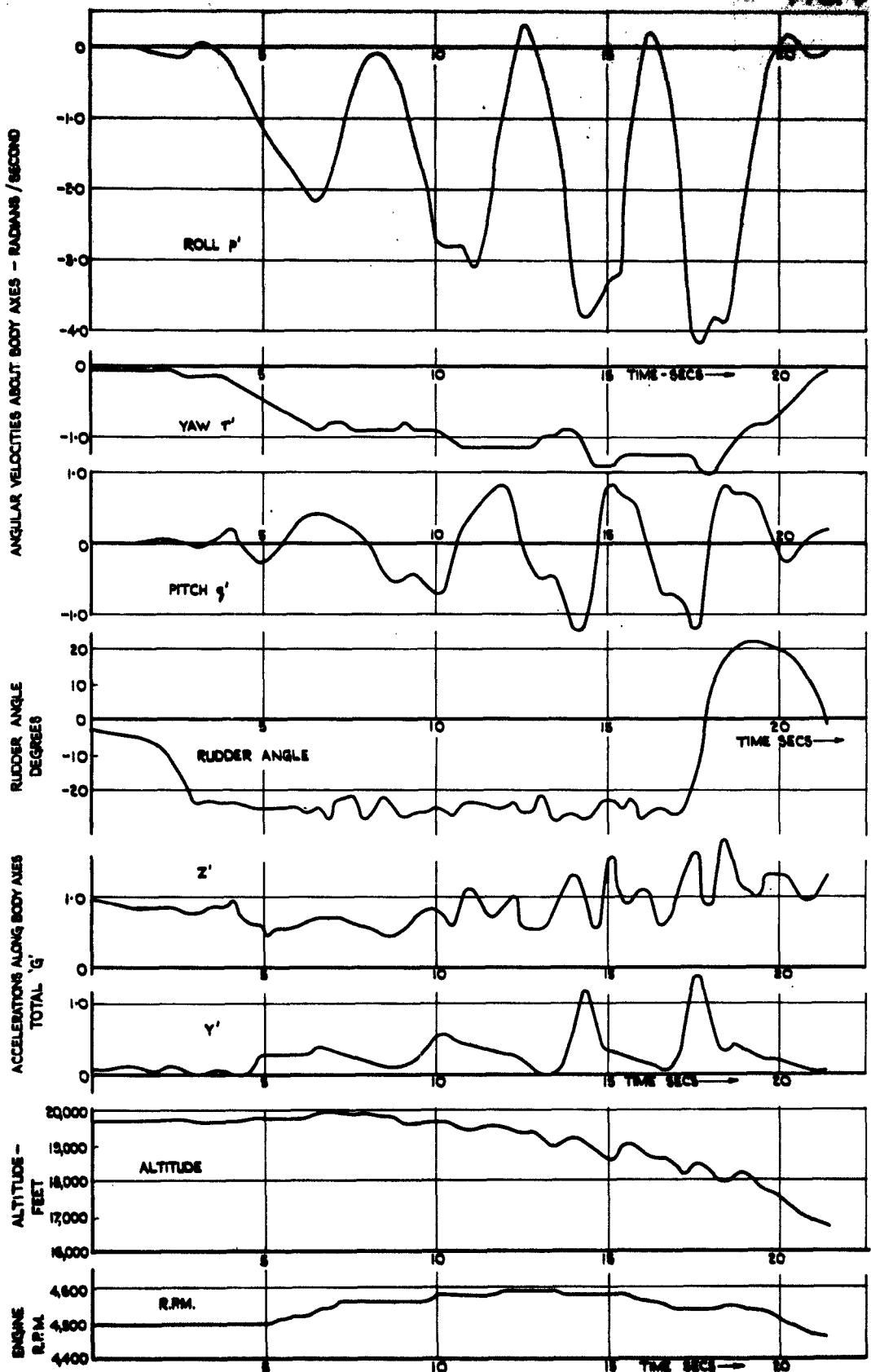


FIG. 9 4 TURN NORMAL SPIN TO PORT FROM 20,000 FT.

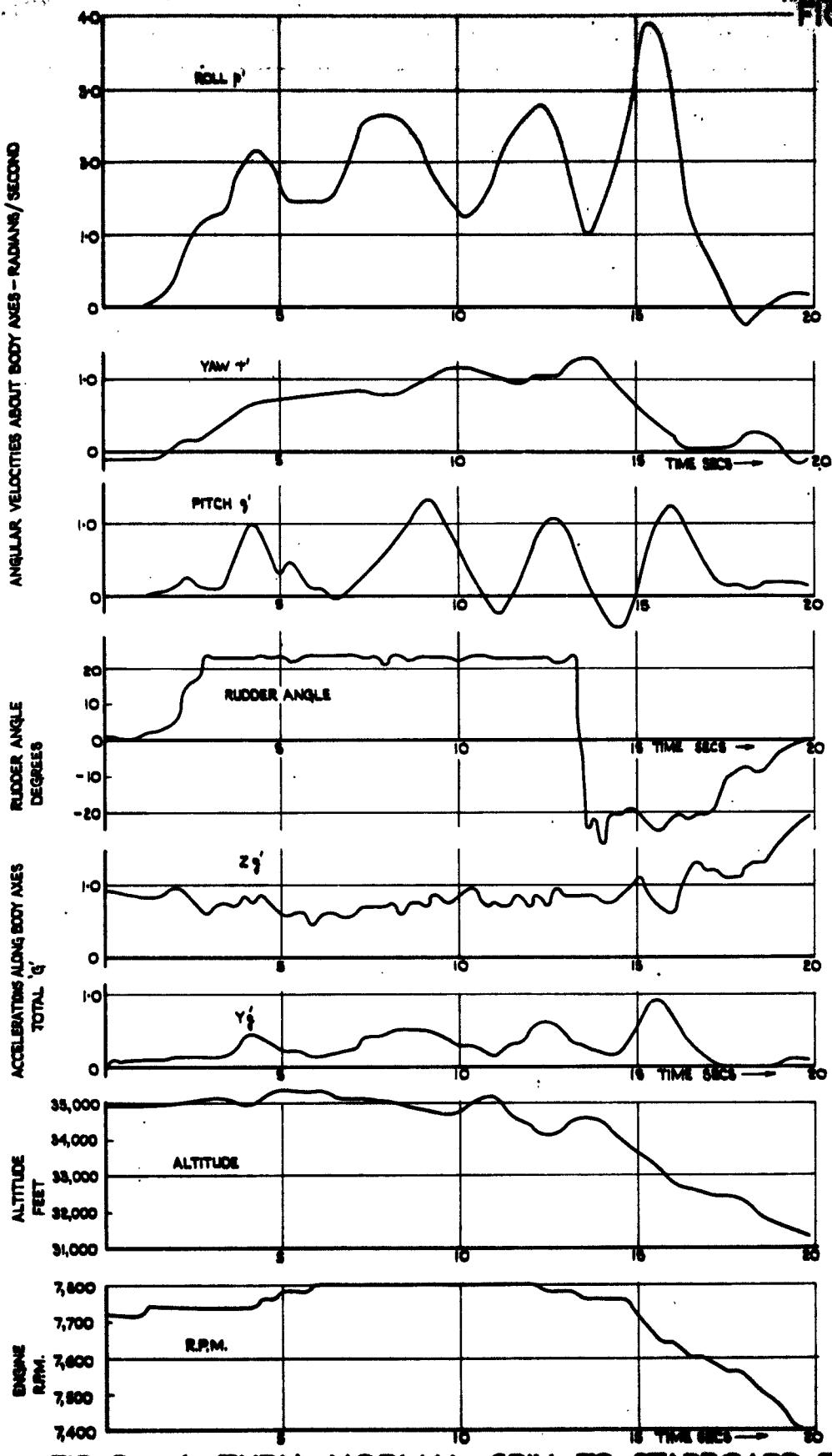


FIG.10 4 TURN NORMAL SPIN TO STARBOARD FROM 35,000 FT.

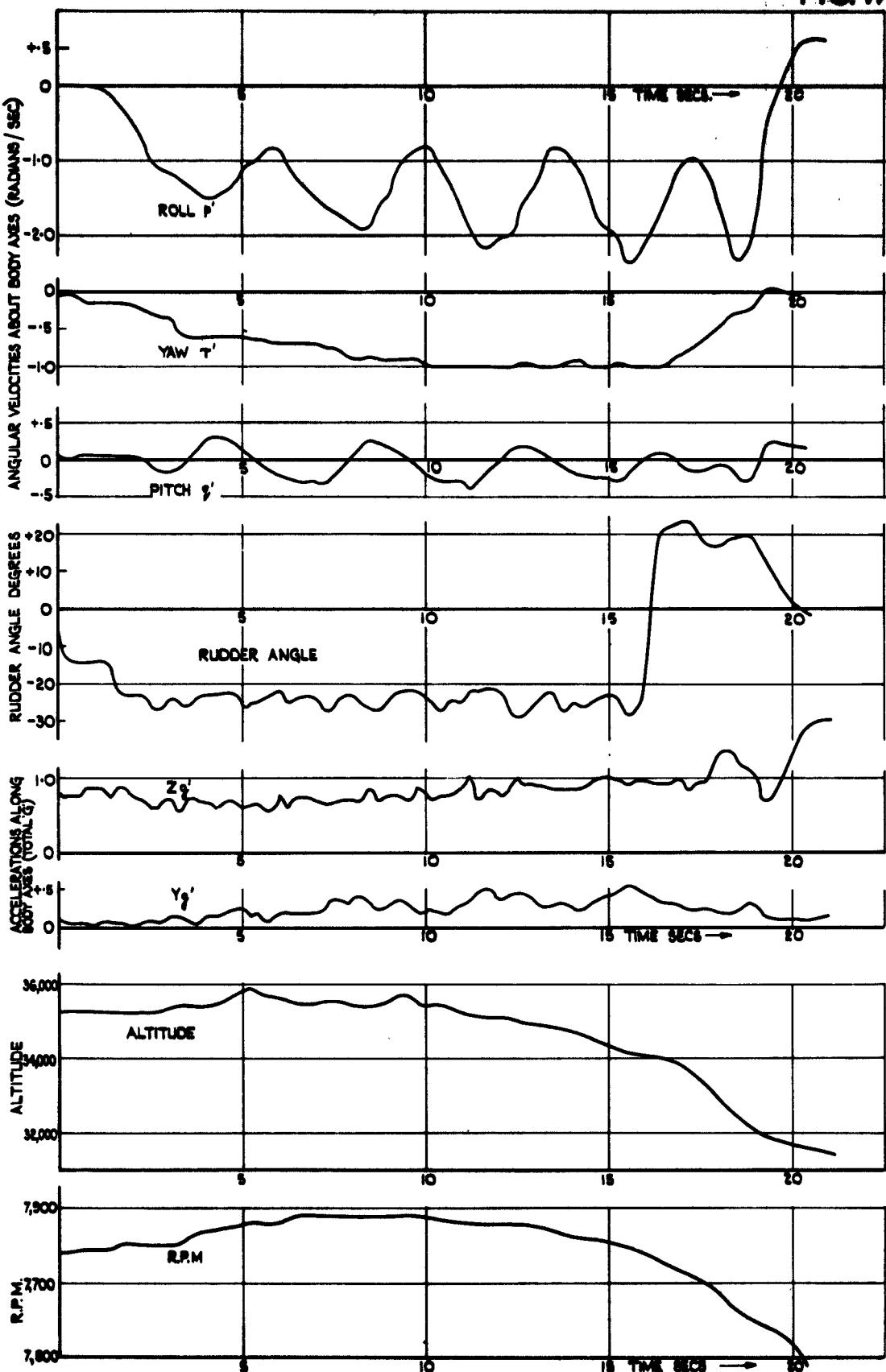


FIG. II 4 TURN NORMAL SPIN TO PORT FROM 35,000 FT.

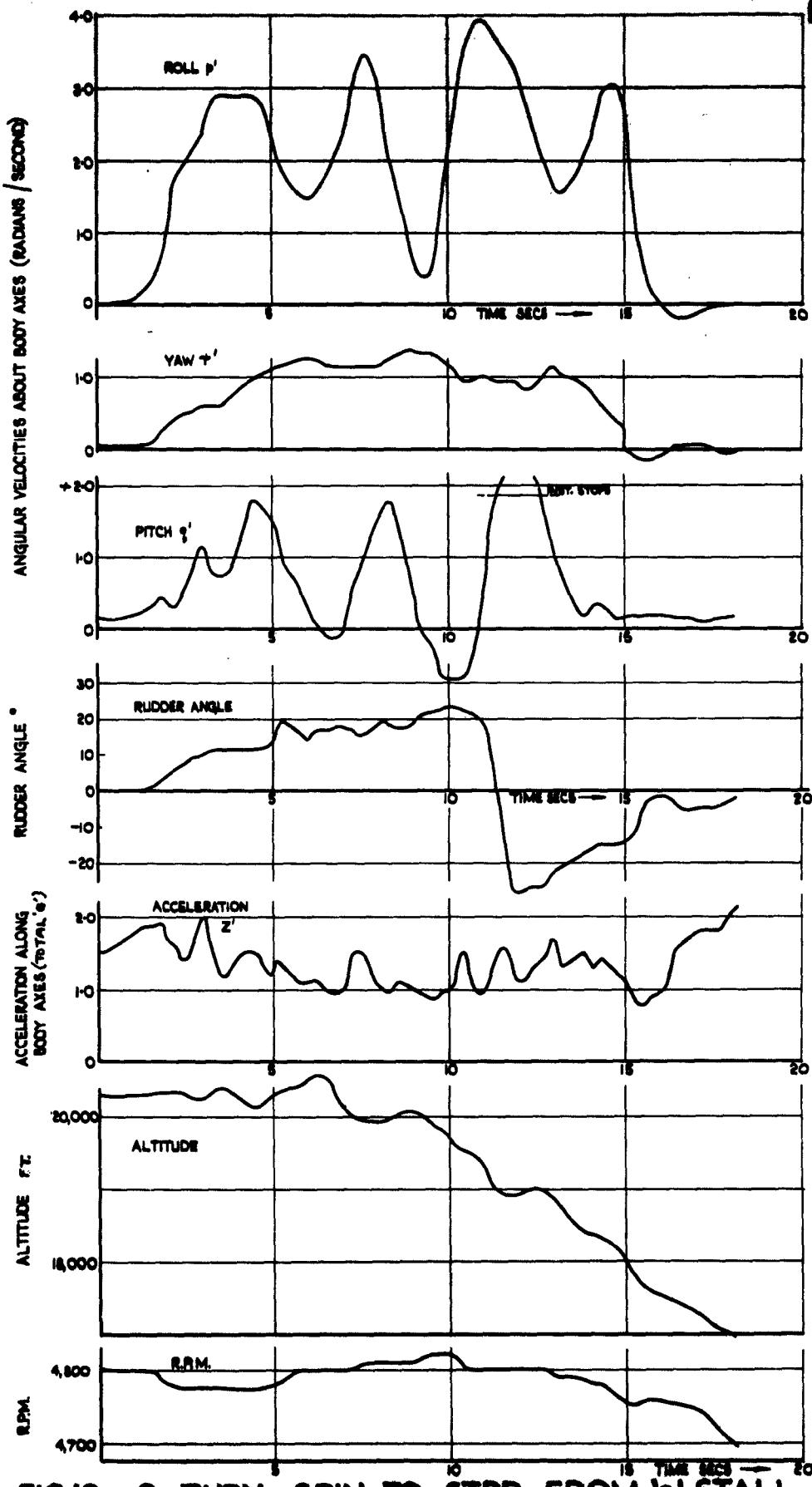
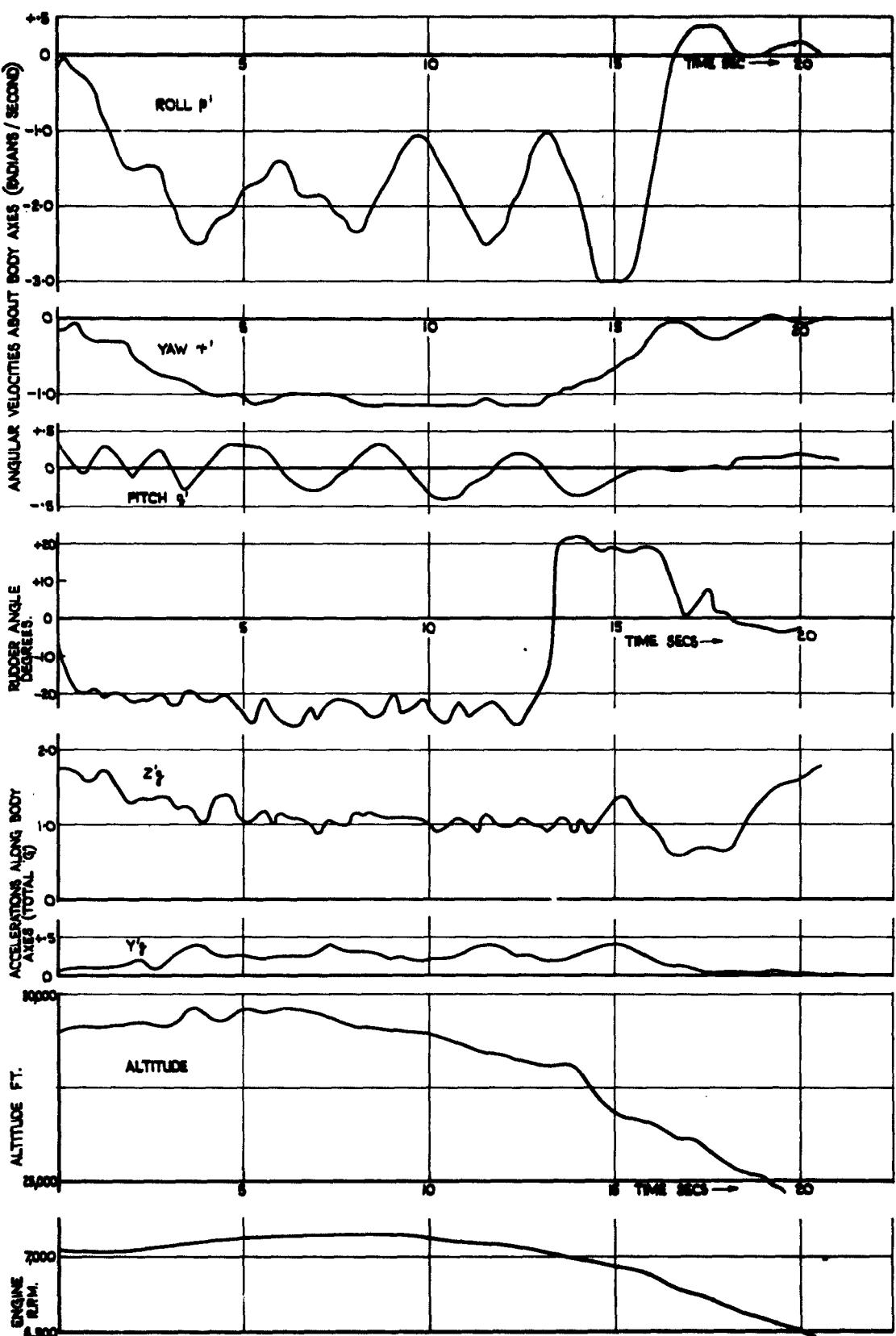
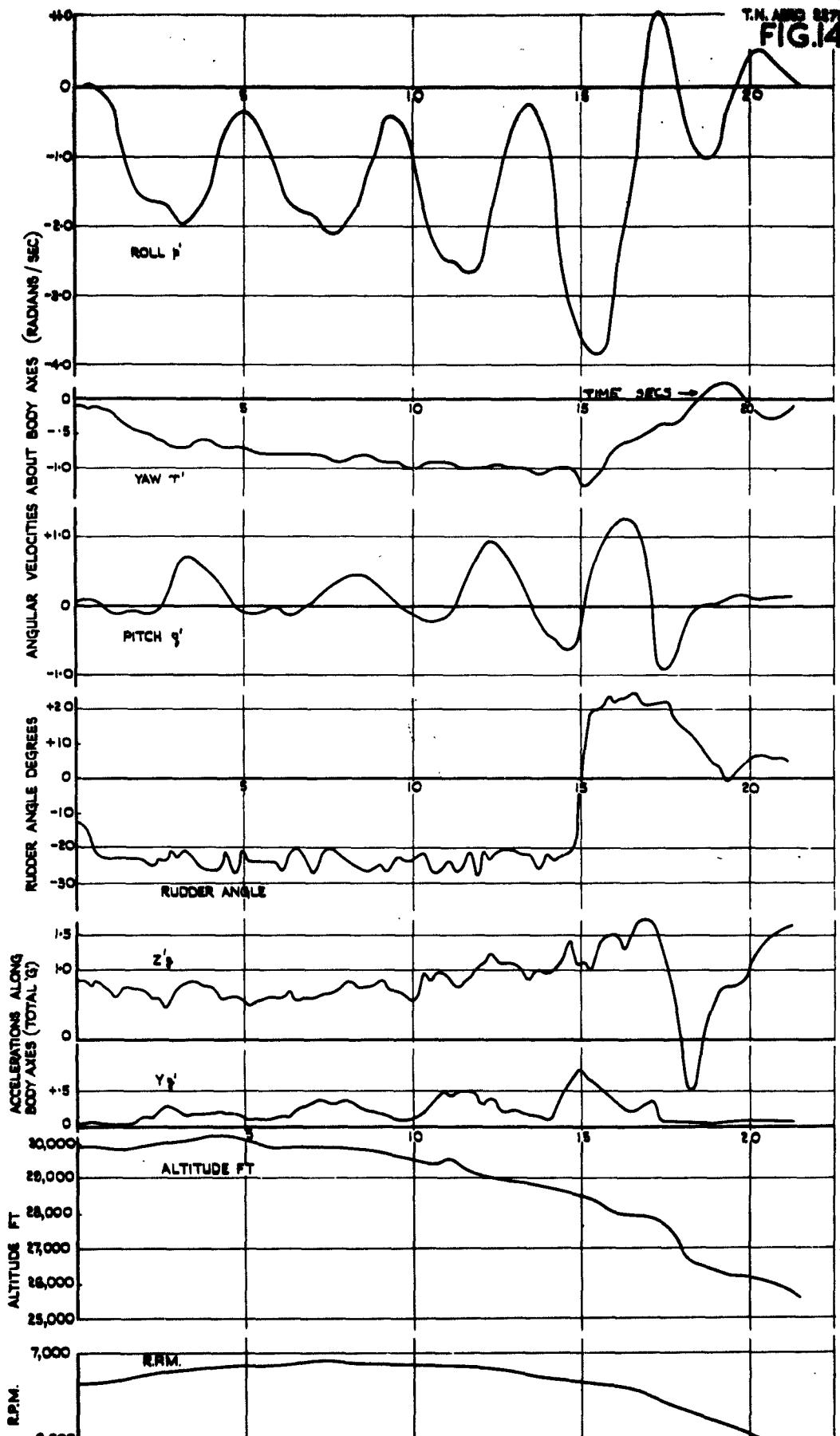


FIG.12 3 TURN SPIN TO STBD. FROM 'g' STALL AT 20,000 FT.

FIG. 13





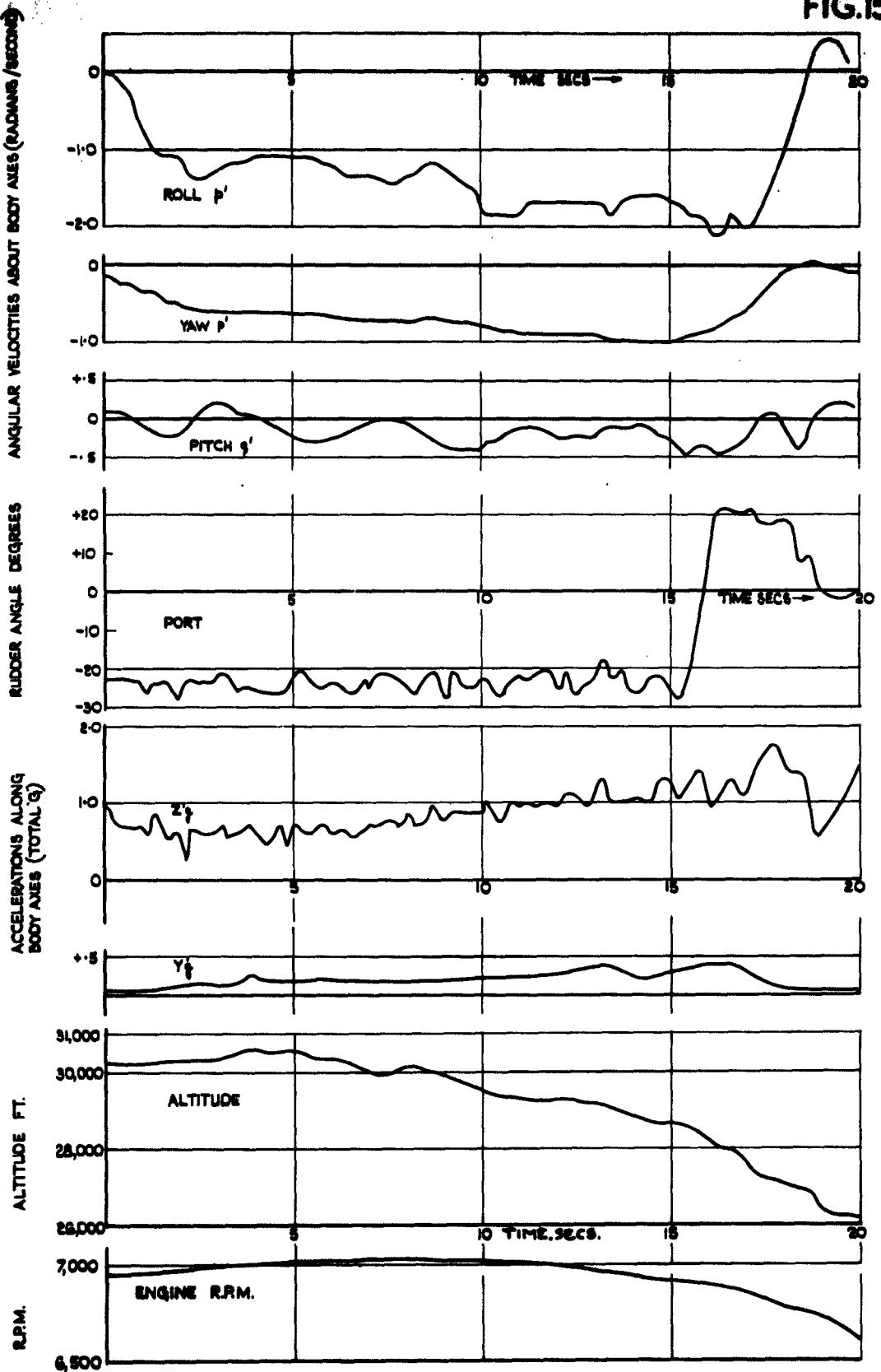


FIG.15 4 TURN SPIN TO PORT WITH 'ANTI-SPIN' AILERON THROUGHOUT.

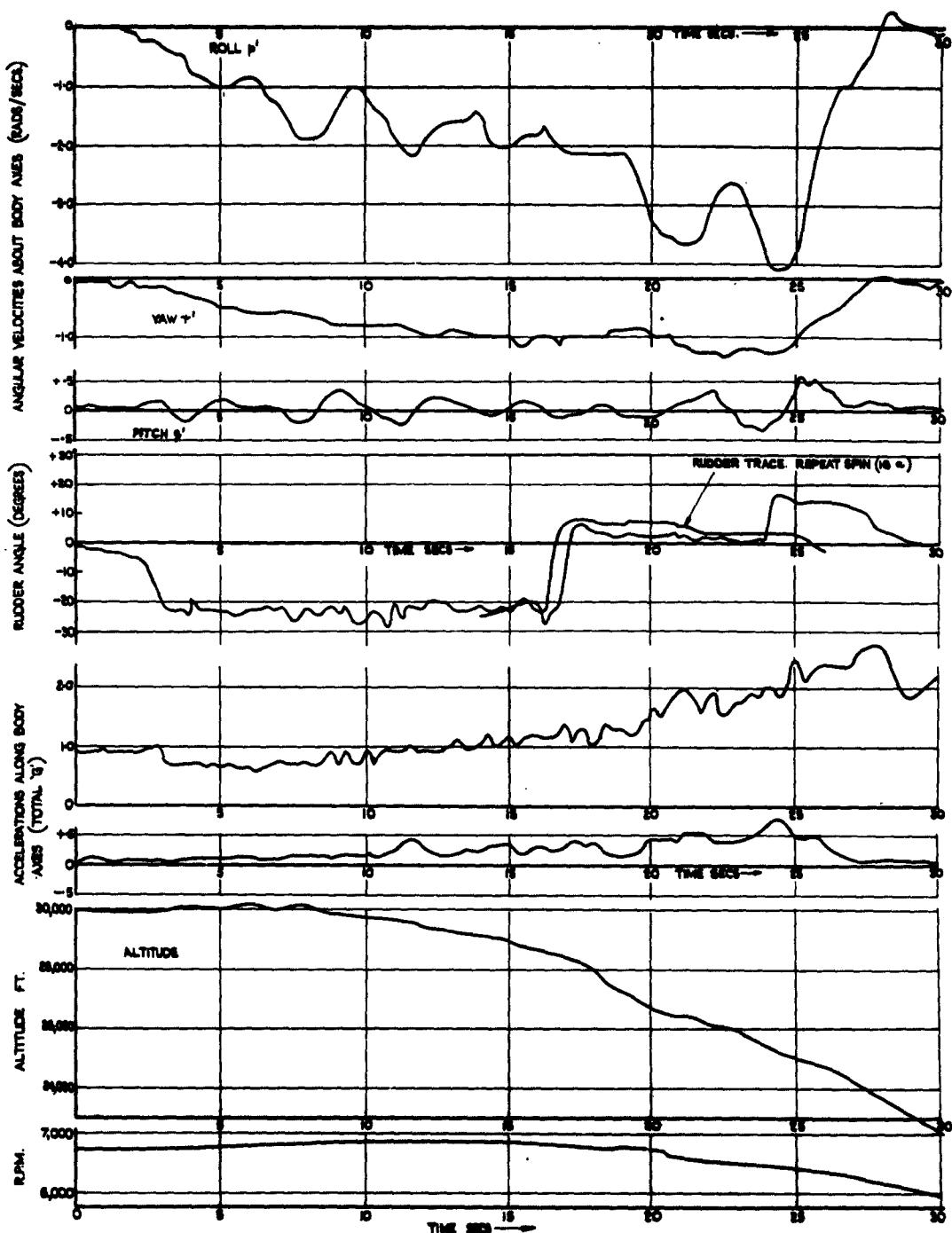


FIG.16 4 TURN NORMAL SPIN, RESTRICTED RUDDER ON RECOVERY.

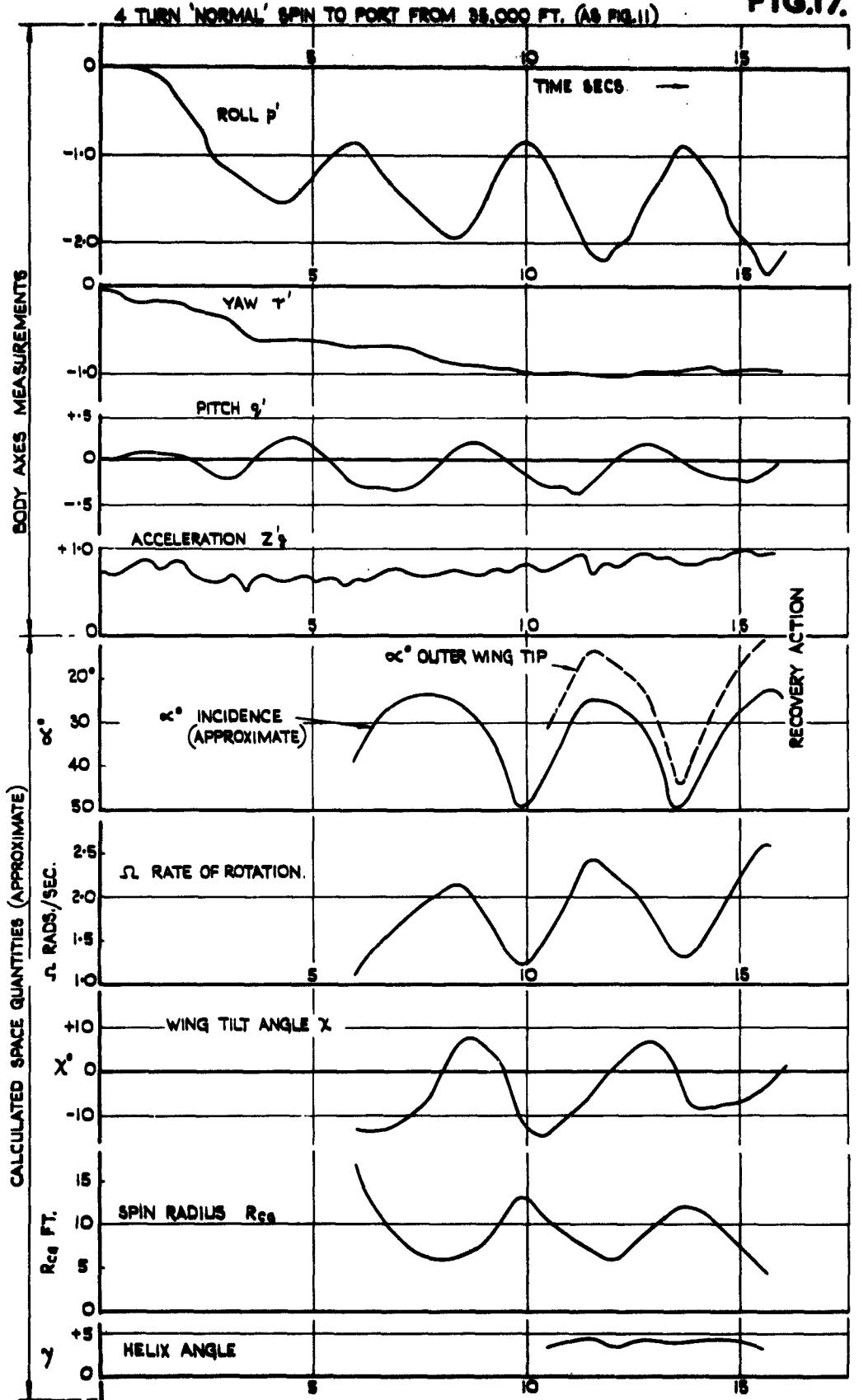


FIG.17. RECONSTRUCTION OF SPACE ATTITUDE AND MOTION.
(NORMAL SPIN, FIG.11).

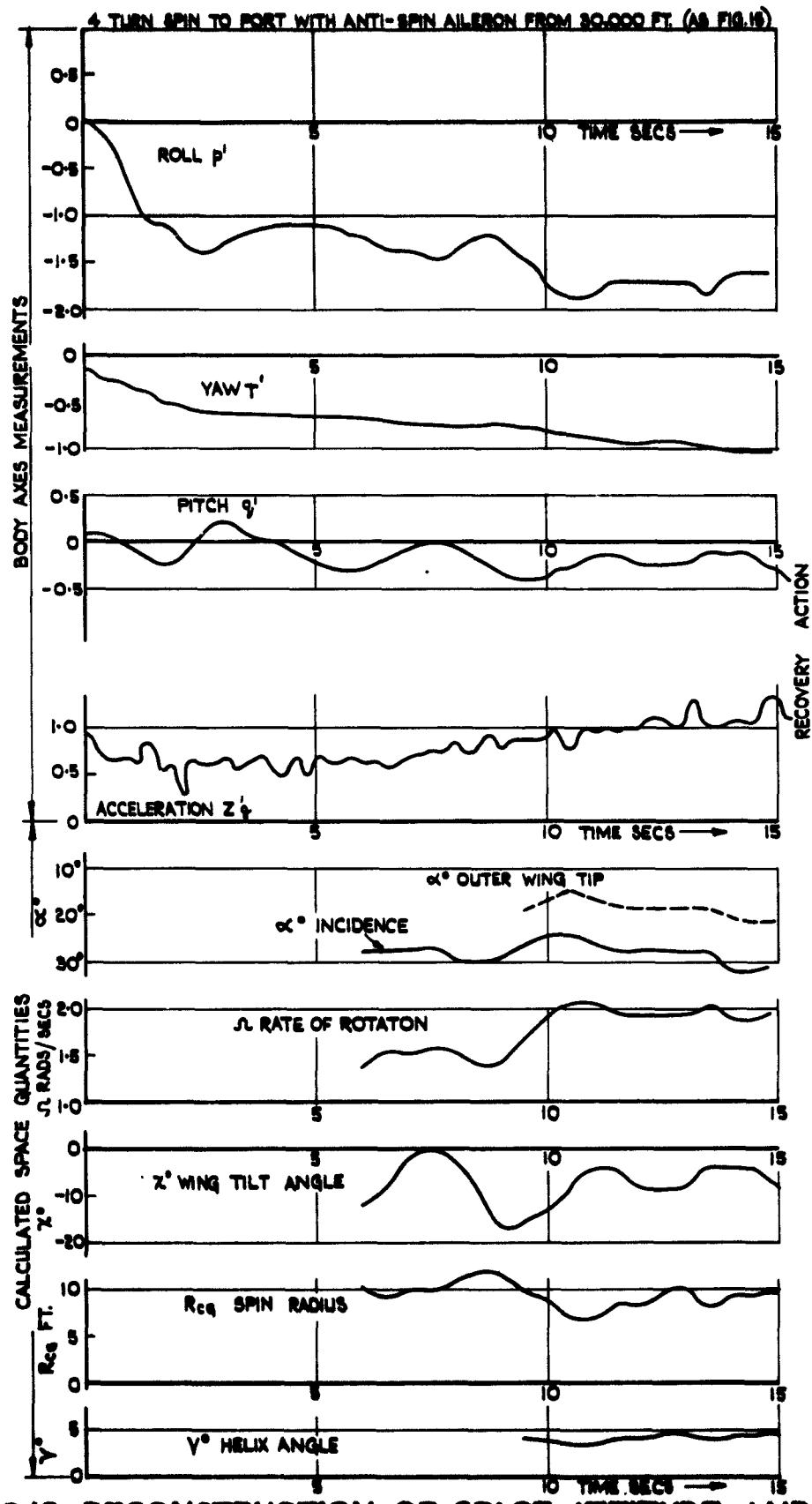


FIG.18 RECONSTRUCTION OF SPACE ATTITUDE AND MOTION
(SPIN WITH ANTI-SPIN AILERON, FIG.15)

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Recovery from four turn spins, by normal recovery action, was always satisfactory; but with rudder only centralised instead of reversed, recovery was doubtful.

The space attitude and motion was deduced from the spin records and some observations made as to the main features of the oscillations.

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